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Small Floodplain Pools as Habitat for Fishes and Amphibians: Methods for Evaluation

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INTRODUCTION: Small floodplain pools (less than 2 m deep, less than 500 m^2) are inhabited by some of the least common fishes in large river systems: species adapted morphologically and physiologically to shallow, periodically hypoxic water with wide variation in temperature (Baker, Killgore, and Kasul 1991; Hoover and Killgore 1998). They are also inhabited by larval salamanders and frogs unable to exploit large, permanent lakes and streams: species adapted reproductively and developmentally to seasonal pulses of riparian-derived food organisms and water volume (Petranka 1998, McDiarmid and Altig 1999). Many of these species are locally or globally imperiled (LaClaire 1997, Warren et al. 2000). Other species provide recreational and commercial fisheries (Buffler and Dickson 1990, Lund 1995) and efficiently produced, high-quality prey for aquatic, semi-aquatic, and terrestrial predators (e.g., Burton and Likens 1975, Hoover and Killgore 1998).

Traditional habitat assessments of aquatic ecosystems by the Corps, however, have not focused on these inconspicuous, sometimes transient habitats. Although the species known to inhabit pools are well documented, relationships between those populations and specific features of pool habitats are not. This hampers the evaluation of impacts and benefits necessary for civil works projects. Widespread declines in wetland fishes (Hoover and Killgore 1998) and amphibians (Dodd 1997) are focusing greater emphasis on pools as essential habitat. As a result, procedures have been developed for formal documentation and protection of pools (e.g., Colburn 1997). Also, pools are being created for habitat mitigation (Fairchild, Faulds, and Matta 2000) and enhancement (LaClaire 1997).

For the Corps to effectively evaluate or create such habitats, models are required that relate habitat- or landscape-level features to fish and amphibian communities. Such models can be developed from a variety of sources depending on the resources and project requirements of Corps planners. These sources include previously published faunal surveys, historical population and hydrographic data, onsite field studies of fauna-habitat relationships, and laboratory studies of environmental tolerances. Data from such sources can be used to assess habitat suitability of pool size and setting, time of flooding, pool morphometry, and hydraulic characteristics of outflow. Such models are being developed in this work unit, and four examples from ongoing studies are presented below.

POOL AREA MODELS BASED ON PUBLISHED SURVEYS: Published surveys of pool faunas typically include species lists of fishes and amphibians and sometimes can indicate relationships between those communities and characteristics of the pools. Those relationships, even if not directly addressed in the original study, can sometimes be extracted from tabular, graphic, or anecdotal data contained within the publication. One such survey that presented presence/absence data for fishes and amphibians, and information on water body size, was reviewed. Regression analyses were used to identify significant relationships between pool area ($\log_{10}$ transformed, independent variable) and species richness of fishes and amphibians (dependent variables).

A survey of small pools (less than 300 m^2) and small lakes (4500 – 35,000 m^2) in the Oklawaha River drainage of Florida included six water bodies that were studied for over a year and which were inhabited by 16 species of fish and 8 species of amphibians (Dickinson 1949). Fish species richness ranged from 3 to 16 species per pool, and amphibian species richness from 5 to 8 species per pool (Figure 1). Amphibian species richness showed little variation and was not correlated with pool size ($r^2 = 0.02$, $p = 0.97$), but fish species richness showed a significant positive curvilinear relationship with pool area ($r^2 = 0.95$, $p = 0.01$). Larger pools provided habitat for a greater variety of fish, but the relationship indicated that there was little difference in predicted fish species richness over a wide range of pool sizes (e.g., 200-6000 m^2). Thus, habitat quality of small pools, based on size alone, was not substantially different than medium-sized pools.

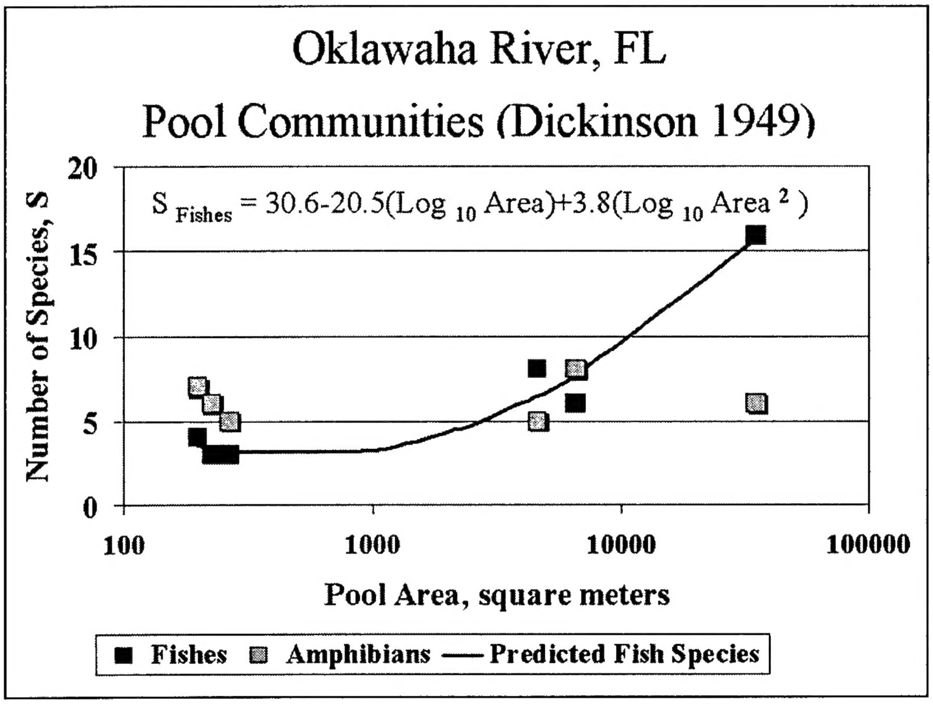

Figure 1. Fish species richness model, based on previously published data

Results are consistent with intuition. Fishes can better disperse to and survive in pools that are larger, and more persistent. Small, transient pools are less likely to be colonized and the water quality extremes there will make them all but inhospitable except to a handful of wetland specialists. Adult amphibians, however, travel overland and can easily disperse to pools regardless of size. They are less likely to occupy larger pools with fishes due to predation and competition for food. Their larvae are aquatic for short periods and are tolerant of water quality extremes (Bachman et al. 1986, Kutka and Bachman 1990, McDiarmid and Altig 1999). Amphibians can survive in transient habitats inhospitable to fishes. Models based on published surveys like this, however, allow relative value of pool size to be objectively determined. They can then be used in habitat evaluation studies as models of Habitat Suitability (U.S. Fish and Wildlife Service (USFWS) 1980). In this case, number of species could serve as a Suitability Index by standardizing output on a 0 to 1 scale (e.g., by dividing by maximum number of species).

This methodology is easy to perform at virtually no cost, and published faunal surveys are available for many parts of the United States including the Southeast (e.g., Moore 1970; Light, Darst, and Grubbs 1995) and Midwest (e.g., Kenk 1949, Collins and Wilber 1979). Effective use of those data in habitat evaluations is problematic, however, for several reasons. Fauna-level surveys (as opposed to population-based surveys) are usually intensive rather than extensive in scope, with low sample sizes (few sites) that result in patterns that are statistically weak or biased. For example, in the Oklawaha data (Dickinson 1949), the relationship, although significant, is largely determined by a single point (Figure 1). Also, many such surveys do not report habitat variables relevant to environmental planners. Dickinson (1949) reported information on other physical variables (e.g., depth, permanence, landscape) but not consistently for all locations, and relevant information on distance to nearest water body, flood frequency, etc., was not reported. Unfortunately, usable vertebrate surveys of small floodplain pools do not exist for most drainages, making the necessary habitat and fish data unavailable to Corps planners.

HYDROGRAPH-BASED MODELS FROM HISTORICAL RECORDS: Relationships between river stages and pool fauna can be determined from recent (unpublished) historical records. Hydrographic data exist for most major streams in the United States, and these can be accessed via the Internet, Corps District Records, or U.S. Geological Survey (USGS) records. Faunal data exist in state resource databases (e.g., Natural Heritage) and as museum records at local ichthyological and herpetological collections of colleges, universities, and museums of natural history. Data available from some regional institutions can be substantial (Poss and Collette 1998). The authors are analyzing relationships between river stages and pool communities of the Ouachita River in Louisiana based on hydrographic data (U.S. Army Engineer Vicksburg District), historical fish surveys (University of Louisiana at Monroe), and ongoing surveys (unpublished data).

Depending upon rainfall, water temperature, and frequency of flooding, one to four floodplain pools form on the Ouachita River floodplain at Lazarre Point, West Monroe, LA. Records for 36 species of fishes in these pools made over a 25-year period are available (Table 1). Fish communities are noteworthy for the diversity of recreationally important species (sunfishes, crappies, largemouth bass), commercially important species (buffalos, channel catfish, freshwater drum), shiners (*Notropis* spp.), and darters (*Etheostoma* spp.). Remarkable among the fishes, though, is the paddlefish (*Polyodon spathula*), a species traditionally considered riverine (Figure 2). Young paddlefish, however, are known to inhabit wetlands, such as sloughs, backwaters, and oxbow lakes (Allen 1911, Hildebrand and Towers 1927, Hoxmeier and DeVries 1997).

In 1993, 21 adult paddlefish were collected from the Ouachita pools, an unprecedented record since a single specimen of paddlefish was recorded only once prior to this (in 1980). The hydrograph indicated that although the pools were cut off from the river that year, they had been connected during a two-month period the year before, and a six-month period the year prior to that (Figure 3). Size range of paddlefish, 807-1013 mm total length, was consistent with 1- to 2-year-old fish from Louisiana (Reed, Kelso, and Rutherford 1992), so they probably entered the pools either in 1991 or 1992, during extensive and prolonged flooding, or during the year afterwards, during minor, brief flooding. Young paddlefish presumably enter wetlands to feed on zooplankton, which is abundant in low-velocity areas. Warmer water temperatures of these shallow water bodies also enhance rapid growth.

Table 1 **Fishes Collected from Floodplain Pools of the Ouachita River, LA**
Polyodon spathula, paddlefish
Lepisosteus oculatus, spotted gar
Amia calva, bowfin
Dorosoma cepedianum, gizzard shad
Dorosoma petenense, threadfin shad
Cyprinus carpio, common carp
Notemigonus crysoleucas, golden shiner
Notropis amnis, pallid shiner
Notropis maculatus, taillight shiner
Notropis texanus, weed shiner
Opsopoeodus emiliae, pugnose minnow
Erimyzon sucetta, lake chubsucker
Minytrema melanops, spotted sucker
Ictiobus bubalus, smallmouth buffalo
Ictiobus cyprinellus, bigmouth buffalo
Ictalurus punctatus, channel catfish
Esox americanus, grass pickerel
Fundulus chrysotus, golden topminnow
Fundulus notatus, blackstripe topminnow
Fundulus olivaceus, blackspotted topminnow
Gambusia affinis, western mosquitofish
Labidesthes sicculus, brook silverside
Lepomis cyanellus, green sunfish
Lepomis gulosus, warmouth
Lepomis humilus, orangespotted sunfish
Lepomis macrochirus, bluegill
Lepomis marginatus, dollar sunfish
Lepomis megalotis, longear
Lepomis microlophus, redear
Micropterus salmoides, largemouth bass
Pomoxis annularis, white crappie
Pomoxis nigromaculatus, black crappie
Etheostoma chlorosomum, bluntnose darter
Etheostoma fusiforme, swamp darter
Etheostoma gracile, slough darter
Aplodinotus grunniens, freshwater drum

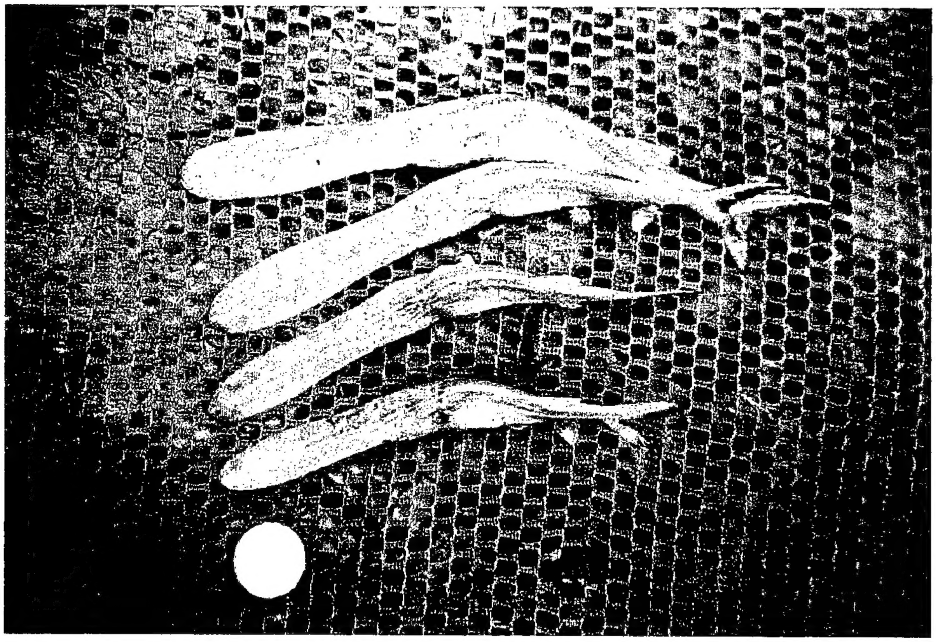

Figure 2. Young-of-year paddlefish (*Polyodon spathula*), the life history stage most likely to move into floodplain pools. A penny appears in the photograph to provide scale. Note the pink, translucent bodies and nearly transparent rostrum

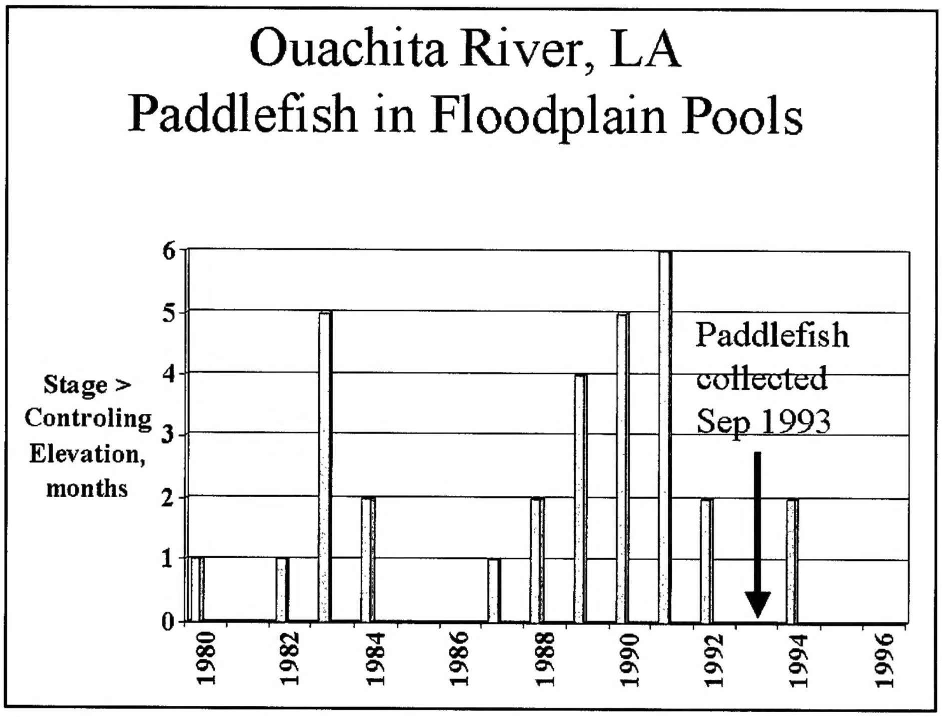

Figure 3. Summary of hydrographic data and occurrence of paddlefish in floodplain pools

Should the pools fail to reconnect, and should rainfall be insufficient to maintain them, water temperatures may become physiologically stressful and fish could face dessication. During the 1980-1997 period of record, the Ouachita pools have been separated from the river for periods as long as 27-34 months, and ponds have dried. This is unusual, however. During most years, pools are connected for one to several months sometime during January to June. Even when they do not connect, rainfall may be sufficient to maintain them, as was the case in 1993 when the paddlefish were collected. At that time, pools had been isolated from the river for 16 months and the paddlefish collected from them were large and robust (George et al., in revision).

Associating hydrographic data with fish community data can have important management implications. Representative hydrographs from periods of record can be used to identify representative stages for different months of the year, and these can be used to evaluate quality of pools based on their position relative to observed stages and the controlling elevation (stage at which pools become connected to the river). Such analyses require moderate analytical effort (i.e., to interface hydrographic and biological databases), but extensive effort may be required to compile biological data if museum records exist only for individual lots of species, or if state databases (e.g., Natural Heritage) are based on individual collection reports. Also, areas with repeated sampling (and specimens available as vouchers) are likely only to occur in the vicinity of universities or colleges.

HABITAT-BASED MODELS FROM FIELD SURVEYS: Empirical relationships between specific habitat features of floodplain pools and vertebrate populations can be used as models of habitat quality. Such relationships require a standardized method of sampling discrete microhabitats within individual pools, and macrohabitats among pools. For these studies, we have used Plexiglas light traps. These traps provide point samples that allow the abundance of individuals to be associated with a specific depth, distance from shore, and type of cover. Our target species, initially, was the marbled salamander (*Ambystoma opacum*) (Figure 4). Although this species is not mentioned as an imperiled species in some reviews of threatened and endangered amphibians (e.g., Dodd 1997, LaClaire 1997), it has recently been listed in several areas of its range (Table 2).

Table 2
Status of the Marbled Salamander in the United States

State	Status	Source
Massachusetts	Threatened	Massachusetts Division of Fisheries and Wildlife (report)
Michigan	Threatened	*www.dnr.state.mi.us/pdfs/wildlife/TE_animals.pdf*
New Hampshire	Endangered	*www.wildlife.state.nh.us/nongameendlist.htm*
New York	Special Concern	*www.dec.state.ny.us/website/dfwmr/wildlife/endspec/*

During the period March-May 2001, 11 pools ranging in size from 3-54 m (maximum dimension) in the lower Mississippi Basin were sampled: Mississippi River and Pearl River drainages, MS, and Bayou Meto system, AR. Pools were characterized according to landscape (agricultural, woodland edge, woodland), sampled using overnight sets of light traps, and habitat was recorded for each trap (N = 66). Depth and distance from shore were measured. Submersed cover was ranked on a 5-point scale based on increasing diameter of cover type: open water, 0; vegetative litter, 1; grasses and forbs, 2; twigs and brush, 3; logs and other large woody debris, 4. If more than one cover type was

Figure 4. Larval marbled salamander (*Ambystoma opacum*) collected in a floating light-trap from a small wooded pool

present, both were recorded and the average of the two values was used for the trap. Five water quality parameters were also measured: turbidity, water temperature, conductivity, pH, and dissolved oxygen.

Larvae of marbled salamanders were absent from pools on agricultural land; numbers were lower in the pools at woodland edges (mean = 1.0, SD = 1.48) than in woodlands (mean = 4.1, SD = 8.12). Abundance was not significantly correlated with any measured water quality parameter, or with trap depth or distance to shore. Abundance was significantly correlated with type of cover ($r^2 = 0.33$, $p < 0.0001$). Relationship between abundance (log-transformed, dependent variable) and cover type (qualitative index, independent variable), was linear (Figure 5). The data suggest that pool size is less important to marble salamander recruitment than availability of woody debris. This is consistent with previous field studies showing that mole salamanders are relatively insensitive to certain kinds of water quality fluctuations (i.e., hypoxia) and prefer small pools with high canopy (Bachman et al. 1986, Kutka and Bachman 1990).

Preliminary data and the available literature indicate that small pools excavated on reforested agricultural land can offer suitable habitat for marbled salamanders over a wide range of water quality and pool morphometry conditions. Based on preferential use of pools in different settings (forested versus non-forested), and on microhabitats utilized (adults laying eggs under logs, larvae using submersed logs as hiding places), the primary determinant of habitat quality appears to be availability of large woody debris. Reproductive success, however, will also be influenced by stochastic abiotic factors (e.g., rainfall) and the availability of small, preferred prey of salamanders (e.g., zooplankton, seed shrimp, scuds, larval midges) rather than larger, hard-bodied invertebrates (e.g., dragonfly naiads, beetles)(Petranka and Petranka 1980, Semlitsch 1987, McWilliams and Bachman 1988). Pool setting and morphometry can optimize these factors, if the pool is in a small depression (e.g., to accumulate runoff from limited rainfall) and if it is sufficiently deep (e.g., to permit the development of crustacean assemblages). Pool morphometry, however, may be directly associated with habitat quality of other species of amphibians and with fishes. Habitat models are being developed for the mole salamander (*Ambystoma talpoideum*), tadpoles of several frogs and toads, larvae of several fishes, and adults of certain small species of fish, including the banded pygmy sunfish (*Elassoma zonatum*).

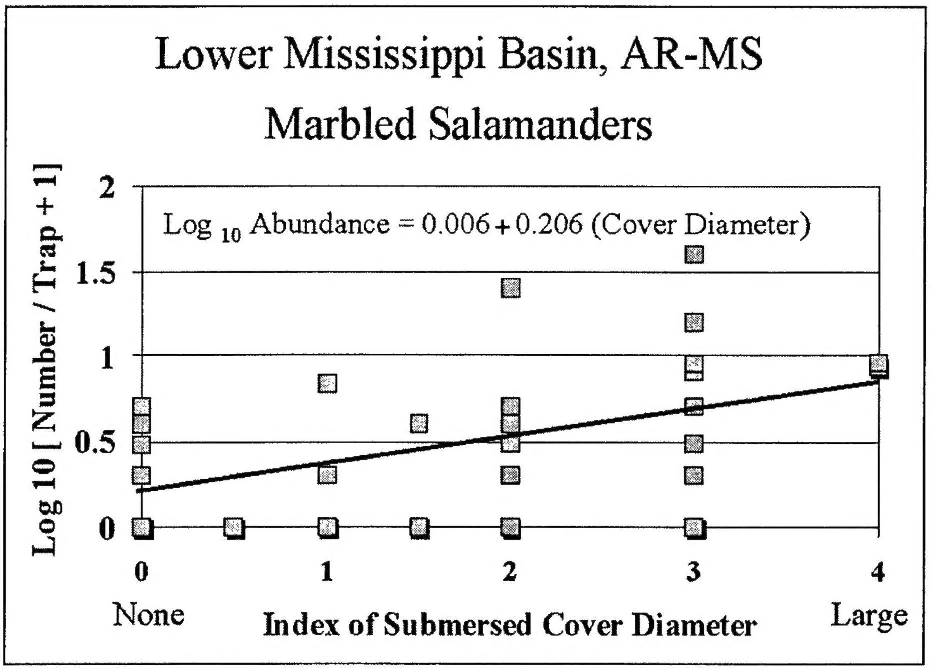

Figure 5. Marbled salamander habitat model

This methodology can be performed at moderate cost but is labor-intensive and requires a familiarity with larval amphibian taxonomy. It also requires that sampling be conducted during a year of typical hydrologic conditions or during multiple years. It offers many advantages, however, including site or species specificity. With appropriate sampling design, the database can generate highly predictive and broadly applicable models. Finally, it provides synoptic sampling of all photopositive organisms (most species inhabiting floodplain pools), and can be used to generate organism-habitat relationships for a wide variety of taxa.

HYDRAULIC ENDURANCE MODELS FROM LABORATORY STREAM STUDIES: The likelihood of pools being colonized by fishes is a function of the dispersal ability of individual species. Dispersal ability, in turn, is determined by the swimming endurance of fishes, i.e., the time a fish can swim at a given speed. Most studies of fish swimming abilities have been conducted on obligate riverine species (Adams et al. 1997; Adams and Parsons 1998; Adams, Hoover, and Killgore 1999, 2000). Many wetland fishes in general, and pool-dwelling species in particular, share common morphologies (Hoover and Killgore 1998). Pool-dwellers such as gars (*Lepisosteus* spp.), bowfin (*Amia calva*), and topminnows (*Fundulus* spp.) have rearward-placed dorsal fins, cylindrical bodies, flat heads, thick peduncles, and broad round tails. Others, such as pirate perch (*Aphredoderus sayanus*), fliers (*Centrachus macropterus*), and sunfishes (*Lepomis* spp.), have centrally placed dorsal fins, compressed, deeper bodies, with symmetrical dorsal and ventral contours. These forms are associated with rapid acceleration and slow, careful maneuvering, respectively. Swimming endurance data, however, are not available for pool-dwelling fishes of either group. This makes assumptions regarding their dispersal abilities tenuous, and the planning of pool position (relative to other water bodies) liable to failure. To evaluate swimming abilities of an "accelerator" species, bowfin (*Amia calva*) were tested.

Juvenile bowfin (75-101 mm TL) were collected 04 May 2001 from a small (7 by 36 m), shallow (< 1 m) floodplain pool of Bayou Meto, AR (Figure 6). Other fishes in the pool were banded pygmy sunfish (*Elassoma zonatum*), western mosquitofish (*Gambusia affinis*), golden topminnow (*Fundulus chrysotus*), and starhead topminnow (*Fundulus dispar*). All of these species are small (less than 50 mm) with a common shape adapted for swimming based on rapid acceleration. Bowfin were acclimated to laboratory conditions and subjected to swimming endurance trials in a Blazka-type swim tunnel. Each bowfin was tested only once; it was habituated in the tunnel for a minimum of 4 hr, subjected to a specific water velocity, and endurance (time-to-fatigue) was recorded. Bowfin were not strong swimmers. Sustained swimming (more than 200 minutes) occurred at 5 cm/s, although one fish exhibited sustained swimming at 25 cm/s. Prolonged swimming (30 s to 24 min) occurred at 15-45 cm/s, burst swimming (less than 30 s) at 55 cm/s. There was a significant negative linear relationship between water velocity and endurance ($r^2 = 0.74$, $p < 0.0001$). Using a reference water velocity of 45 cm/s, this model estimates bowfin swimming time of 0.86 min (Figure 7). This value is intermediate between the estimated swim time of 0.33 min for juvenile pallid sturgeon (*Scaphirhynchus albus*), a slightly larger fish that frequently rests on the river bottom, and the estimated swim time of 2.61 min for an adult Topeka shiner (*Notropis topeka*), a somewhat smaller species that swims by continuous cruising (Adams, Hoover, and Killgore 1999, 2000).

Figure 6. Juvenile bowfin (*Amia calva*) used in laboratory swim tunnel study. Growth rate and other physical characteristics of these fish were monitored for 6 months subsequent to swimming performance experiments (Hoover and Strange 2002)

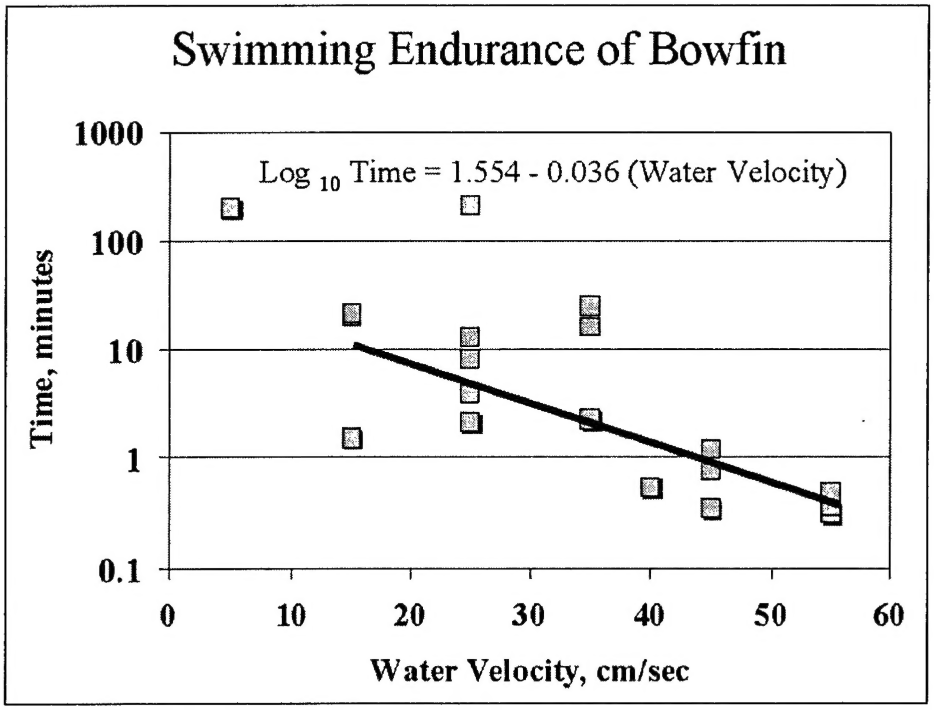

Figure 7. Bowfin swimming performance model

Data suggest low to moderate dispersal abilities for juvenile bowfin, a result consistent with their occurrence in small pools close to larger water bodies. For any given distance from such a water body, low-volume, forested pools are likely to drain more slowly than high-volume, open pools, so that outlet channels of the former are more likely to be navigated by fish entering pools, or resisted by fish seeking to remain in them during freshets. Applicability of these data to other species requires additional testing with similar and disparate forms. To date, the morphologically similar Florida gar (*Lepisosteus platyrhincus*) and disparate banded pygmy sunfish (*Elassoma zonatum*) have been tested. Additional species will need to be evaluated to determine similarity within and between body types of pool fishes, and to relate their swimming abilities to habitats. When completed, these data can be used by planners to determine optimal distance of pools from water bodies and water outlet velocities (based on outlet dimensions, gradient, and pool volume).

SUMMARY: Small floodplain pools have long been recognized as important habitats for aquatic vertebrates, but they have rarely been considered in Corps flood control projects. The large number of regionally imperiled fishes and amphibians that use these habitats, and the ease with which they can be created, make them attractive candidates for mitigation or for habitat enhancement. Models for the evaluation of habitat quality, or for the development of construction guidelines, however, do not exist. Correlation or regression analyses can be used to create such models, provided a database exists that relates some functional response of fishes or amphibians, to some controllable habitat parameter. This can be done most expediently using published surveys (e.g., Figure 1), but few have been published that are sufficiently robust to generate broadly useful relationships. Field surveys offer the best opportunity of identifying workable organism-habitat relationships (e.g., Figure 5), but these are labor-intensive and time-consuming. Analysis of historical data (e.g., Figure 3) and use of experimental studies (Figure 7) offer cost-effective alternatives. In this work unit, a literature review, historical data,

field surveys, and experimental studies have been combined to identify and quantify relationships between physical habitat of pools and the abundance and diversity of fishes and amphibians so that Corps planners can effectively evaluate and utilize pools in environmental studies.

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REFERENCES

Adams, S. R., and Parsons, G. R. (1998). "Seasonal changes in swimming performance, metabolic rate, and hematocrit of smallmouth buffalo (*Ictiobus bubalus*)," *Physiol. Zool.* 71, 350-358.

Adams, S. R., Hoover, J. J., and Killgore, K. J. (1999). "Swimming endurance of juvenile pallid sturgeon, *Scaphirhynchus albus*," *Copeia* 1999, 802-807.

Adams, S. R., Hoover, J. J., and Killgore, K. J. (2000). "Swimming performance of the Topeka shiner (*Notropis topeka*), an endangered midwestern minnow," *Am. Midl. Nat.* 144, 178-186.

Adams, S. R., Parsons, G. R., Hoover, J. J., and Killgore, K. J. (1997). "Observations of swimming ability in shovelnose sturgeon (*Scaphirhynchus platorynchus*)," *J. Freshwater Ecol.* 12, 631-633.

Allen, W. F. (1911). "Notes on the breeding season and young of *Polyodon spathula*," *J. Wash. Acad. Sci.* 1, 280-282.

Bachman, M. D., Carlton, R. G., Burkholder, J. M., and Wetzel, R. G. (1986). "Symbiosis between salamander eggs and green algae: Microelectrode measurements inside eggs demonstrate effect of photosynthesis on oxygen concentration," *Can. J. Zool.* 64, 1586-1588.

Baker, J. A., Killgore, K. J., and Kasul, R. L. (1991). "Aquatic habitat and fish communities in the lower Mississippi River," *Rev. Aquatic. Sci.* 3, 313-356.

Buffler, R., and Dickson, T. (1990). *Fishing for buffalo.* Culpepper Press, Minneapolis, MN.

Burton, T. M., and Likens, G. E. (1975). "Energy flow and nutrient cycling in salamander populations in the Hubbard Brook Experimental Forest, New Hampshire," *Ecology* 56, 1068-1080.

Colburn, E. A. (1997). "Certified – a citizen's step-by-step guide to protecting vernal pools." 7th edition. Massachusetts Audubon Society, Lincoln, MA.

Collins, J. P., and Wilber, H. M. (1979). "Breeding habits and habitats of the amphibians of the Edwin S. George Reserve, Michigan, with notes on the local distribution of fishes," *Occ. Pap. Mus. Zool. Univ. Mich.* 686: 1-34 pp.

Dickinson, J. C., Jr. (1949). "An ecological reconnaissance of the biota of some ponds and ditches in north Florida," *Quart. J. Fla. Acad. Sci* 11(2-3), 1-28.

Dodd, C. K., Jr. (1997). "Imperiled amphibians: a historical perspective." *Aquatic Fauna in Peril: The Southeastern Perspective*, G. W. Benz and D. E. Collins, ed., Special Pub. 1, Southeast Aquatic Research Institute, Lenz Design and Communications, Decatur, GA, 165-200.

Fairchild, G. W., Faulds, A. M., and Matta, J. F. (2000). "Beetle assemblages in ponds: Effects of habitat and site age," *Freshwater Biology* 44, 523-534.

George, S. G., Hoover, J. J., Killgore, K. J., and Harrell, S. L. "Floodplain pools as habitat for paddlefish (*Polyodon spathula*)," *Wetlands* (in revision).

Hildebrand, S. F., and Towers, I. L. (1927). "Annotated list of fishes collected in the vicinity of Greenwood, Mississippi, with descriptions of three new species," *Bull. Bur. Fisheries* 43, 105-136.

Hoover, J. J., and Killgore, K. J. (1998). "Fish communities." *Southern forested wetlands – ecology and management*, M. G. Messina and W. H. Conner, ed., Lewis Publishers, Boca Raton, FL, 237-260.

Hoover, J. J., and Strange, T. (2002). "Growth, condition, and color of juvenile bowfin in medium-sized aquaria," *American currents* 28(2), 1-6.

Hoxmeier, R. J. H., and DeVries, D. R. (1997). "Habitat use, diet, and population structure of adult and juvenile paddlefish in the lower Alabama River," *Trans. Am. Fish. Soc.* 126, 288-301.

Kenk, R. (1949). "The animal life of temporary and permanent ponds in southern Michigan," *Univ. Mich. Mus. Zool. Misc. Publ.* 71, 1-66.

Kutka, F. J., and Bachmann, M. D. (1990). "Acid sensitivity and water chemistry correlates of amphibian breeding ponds in northern Wisconsin, USA," *Hydrobiologia* 208, 153-160.

LaClaire, L. V. (1997). "Amphibians in peril: Resource management in the southeast." *Aquatic Fauna in Peril: The Southeastern Perspective*, G. W. Benz and D. E. Collins, ed., Special Pub. 1, Southeast Aquatic Research Institute, Lenz Design and Communications, Decatur, GA, 307-338.

Leitman, H. M., Darst, M.R., and Nordhaus, J. J. (1991). "Fishes in the forested floodplain of the Ochlockonee River, Florida, during flood and drought conditions," Water Resources Investigations Report 90-4202, U.S. Geological Survey, Tallahassee, FL.

Light, H. M., Darst, M. R., and Grubbs, J. W. (1995). "Hydrologic conditions, habitat characteristics, and occurrence of fishes in the Apalachicola River floodplain, Florida: Second Annual Report of Progress, Oct 1993-Sep 1994," Open file report 95-167, U.S. Geological Survey, Tallahassee, FL.

Lund, J. (1995). "Flatheads and spooneys – fishing for a living in the Ohio River Valley," University Press of Kentucky, Lexington.

McDiarmid, R. W., and Altig, R. (1999). "Tadpoles – the biology of anuran larvae," The University of Chicago Press, Chicago, IL.

McWilliams, S. R., and Bachman, M. D. (1988). "Using life history and ecology as tools to manage a threatened salamander species," *Jour. Iowa Acad Sci.* 95, 66-71.

Moore, W. G. (1970). "Limnological studies of temporary ponds in southeastern Louisiana." *Southwestern Nat.* 15, 83-110.

Petranka, J. W. (1998). "Salamanders of the United States and Canada." Smithsonian Institution Press, Washington, DC.

Petranka, J. W., and Petranka, J. G. (1980). "Selected aspects of the larval ecology of the marbled salamander, *Ambystoma opacu*m in the southern portion of its range," *Am. Midl. Nat.* 104, 352-363.

Poss, S. G., and Collette, B. B. (1995). "Second survey of fish collections in the United States and Canada," *Copeia* 1995, 48-70.

Reed, B. C., Kelso, W.E., and Rutherford, D. A. (1992). "Growth, fecundity, and mortality of paddlefish in Louisiana," *Trans. Am. Fish. Soc.* 121, 378-384.

Semlitsch, R. D. (1987). "Relationship of pond drying to the reproductive success of the salamander *Ambystoma talpoideum*," *Copeia* 1987, 61-69.

U.S. Fish and Wildlife Service. (1980). "Habitat evaluation procedures," ESM 102, U.S. Fish and Wildlife Service, Washington, DC.

Warren, M. L., Jr., Burr, B. M., Walsh, S. J., and 12 co-authors. (2000). "Diversity, distribution, and conservation status of the native freshwater fishes of the southern United States," *Fisheries* 25, 7-29.

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